

**A moored profiling instrument
for observing finescale velocity, temperature and salinity variability
in the coastal environment**

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Long term goals

The long-range goal of our studies is to understand the processes that cause mixing in the ocean. Of particular interest is the turbulence caused by internal wave breaking. Our recent work has revealed strong relationships between finescale shear levels and the intensity of turbulent mixing, and marked spatial variability in the intensity and characteristics of the internal wave field. In particular, we have found enhanced finestructure and microstructure adjacent to rough bathymetric structures. We seek to develop understanding of internal waves near such bathymetry, and their role in mixing the ocean.

Objectives

Our research to date has utilized the free-fall High Resolution Profiler (Schmitt *et al.*, 1988) to obtain samples of the ocean's temperature, salinity, and horizontal velocity fields and the associated dissipation rates of turbulent kinetic energy and temperature variance. While highly successful, this instrumentation is limited in the frequency at which it can be deployed, and by the finite duration of on-site research vessel support. To improve understanding of internal waves in the near-coastal ocean, we are developing a moored profiling instrument system (termed the Moored Velocity Profiler, MVP) able to sample oceanic finescale velocity, temperature and salinity variability autonomously. As with its predecessors (e.g. Cyclesonde and PCM), a key design characteristic of new the instrument is the use of one sensor suite to profile the water column, greatly reducing the cost and uncertainty inherent in using multiple discrete sensors. The major differences between MVP and previous instruments include the drive system (traction) and operational depth range (full-ocean-depth). The objectives of our current grant are to design, construct and field test a prototype of this new instrument, in support of future experiments planned to study internal waves near the continental margins.

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Approach

Our approach is evolutionary in that we are building on experience developed with a similar instrument system designed to obtain hydrographic (T,S vs. P) time series autonomously (Frye *et al.*, 1996). The MVP utilizes the same basic drive system, mechanical layout, controller, CTD, and data logger as the hydrographic profiler. To it we are adding an acoustic travel-time current meter, and accelerometers, tilt sensors, and compass to measure instrument motions. The oceanographic instrumentation are obtained from Falmouth Scientific, Inc. (FSI): their MicroCTD, and a modified version of their 3D-Acoustic Current Meter. The engineering effort is being directed by Daniel Frye of the Institution's Advanced Engineering Laboratory. Toole and Schmitt are providing scientific guidance. Key contributors include Kenneth Doherty (mechanical engineering), Stephen Liberatore (software and electrical engineering) and Alan Hinton (electrical engineering). Technical support of the data analysis effort is provided by Ellyn Montgomery and Gwyneth Packard.

Work Completed

On January 4 of this year, we deployed the prototype Moored Velocity Profiler on the 1500 m isobath south of Woods Hole for a short-duration sea trial. The instrument was recovered on February 25, whereupon the acquired data were downloaded and the technical analysis begun. Follow-up studies of the velocity sensing system were carried out in the WHOI Tow-tank facility. Based on the data acquired from ocean and tow-tank, modifications to the Profiler systems were suggested. A redesign of the Profiler drive- and guide-wheels was carried out to improve instrument performance in the face of biological fouling. Working with FSI, we also implemented a new sensor assembly for the current meter to eliminate wakes off support struts that could contaminate the measurements. The new sensor sting can be mounted remotely from the electronics pressure housing, which improves the hydrodynamics of the Profiler body. The CTD was also moved to improve flow characteristics. The modified MVP system underwent laboratory and dock tests, and was deployed south of Woods Hole on the 1500 m isobath on September 23 for a second sea-trial. It is scheduled to be recovered on November 4-5.

Results

The first sea-trial of the Moored Velocity Profiler verified that our basic concept for obtaining repeated vertical profiles of the ocean's temperature, salinity and velocity fields was viable. Data obtained over a 10-day period in January 1997 showed warmer, saltier upper ocean waters appearing mid-record, to be replaced later by an isolated lens of cold, fresh water. Deeper in the water column, isotherms and isohalines moved vertically 100-200 m at tidal and longer periods. The mean flow at this time was directed northwest, and increased in intensity through the record. Higher frequency motions were also captured. These are particularly striking in the upper ocean where there is indication of vertical phase propagation directed upward with time. Such signals are indicative of internal waves carrying energy downward.

The trial also highlighted shortcomings in the prototype's mechanical design and our implementation of the FSI 3D-ACM current sensor. In light of these, we have made several

modifications to the instrument. The external shell of the Profiler was cut away to put the drive and guide wheels out in the flow. The idea here was to allow any accumulated biological material to flush away. As well, the drive and guide wheels were made much larger, with significantly larger clearances. The instrument is now better able to pass over obstructions on the mooring wire. In addition to being larger, the drive wheel has been scored to have greater traction against the mooring wire, and is being held in contact with the wire at greater spring tension. Dock tests show the magnetic coupler in the drive system, not drive wheel traction, is now the limiting factor in moving the Profiler along the wire.

Working with Falmouth Scientific, Inc., we have also modified the current meter being used on the MVP. Our initial trials for proof-of-concept used FSI's "standard" 3D-Acoustic-Current-Meter mounted to extend horizontally out of the front of the Profiler. We found two problems with this. First, due to space limitations, we had about half of the pressure case sticking out in the flow, with the sensor sting (mounted on the endcap) extending out beyond. The horizontal drag of this assembly, sitting forward of the instrument pivot point about the wire, led to significant (peak to peak nearly 45 degrees) wagging of the Profiler at 5-10 second period. The angular motion of the current meter sting caused a corresponding signal in the observed currents that were difficult to remove completely. Second, we discovered from test runs in the Institution's tow-tank facility that the standard ACM has "blind spots" to incident flows that align with the acoustic paths of the sensor sting. Wakes shed from the sensor struts contaminate the measured current in these cases. In our application with the meter mounted horizontally, the problem appears when the incident current speed approaches the profile speed (~ 30 cm/s).

The new design we arrived at has a modified sting assembly that may be mounted remotely from the electronics pressure case. The sting supports four acoustic paths, as did the original, but presents three paths that are upstream of any strut for incident flows within the forward hemisphere of the instrument. From these three "clear" acoustic paths, estimates of the three Cartesian velocity components relative to the Profiler are directly obtainable. Tow-tank tests verified the performance of the new arrangement. The new acoustic transducer sting mounts on the front face of the MVP body, connected via an oil-filled cable with the electronics pressure case that is totally enclosed within the instrument shell. Perhaps because of the reduction in drag, dock tests done prior to the ocean deployment showed much less tendency for the body to wag about the wire.

The modified prototype Moored Velocity Profiler was again deployed in the ocean in 1500 m of water south of Woods Hole on September 23. Recovery is planned for November 4-5 with evaluation of the instrument performance to follow.

Impacts/Applications

We believe the new Moored Velocity Profiler will prove an exciting and valuable addition to the present suite of oceanographic instruments. In particular, we are planning to use these instruments in a study of internal wave motions about the continental margin: a region characterized by energetic, high-frequency finescale motions.

Transitions

Those prototype Moored Profiler instruments currently in hand and the two MVP's to be constructed will constitute a new Facility at the Woods Hole Oceanographic Institution. It is envisioned that scientific users will have access to these instruments just as they presently have to conventional current meters and CTD's. Moreover, the Moored Profiler technology has been licensed to a commercial company (McLane Research, Inc.) who will be offering these instruments for general sale. We have as well constructed instruments in-house for individual scientific colleagues (see below).

Related projects

An immediate goal of the Moored Velocity Profiler development program is in support of the Littoral Internal Wave Initiative (LIWI) program. We intend to deploy a close-spaced array of three profilers on the continental slope off Virginia to document the frequency-wavenumber characteristics of internal waves generated at / reflected from the bottom.

Our MVP development project is a companion effort to ongoing programs building experience with and enhancing the Moored Profiler, a similar instrument to the MVP that carries only a CTD. The initial development effort of the Moored Profiler has been funded by the U.S. National Science Foundation (grant to J. Toole and D. Frye). Field tests of this instrument are being conducted offshore from Bermuda. A program to add real-time telemetry to the system is being supported by the National Oceanic and Atmospheric Administration through the University Consortium program (grant to J. Toole, D. Frye and R. Pickart). Lastly we have constructed two Moored Profiler units for colleagues at the Institute fur Meereskunde in Germany, and the U.K.'s Southampton Oceanographic Centre.

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